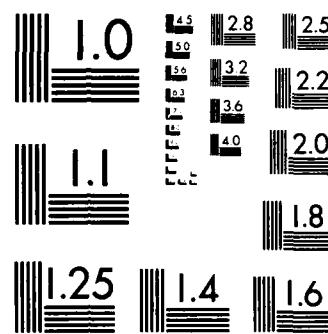


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Technical Report No. 20

THE MODELLING OF ORIENTATION IN PLANAR
POLYMER WELDING FLOWS

BY

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July 1, 1987

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THE MODELLING OF ORIENTATION IN PLANAR POLYMER WELDING FLOWS

By Kung-Hwa Wei

Welding flows occur in many important polymer processing operations. When two streams of molten polymers meet and form a weld interface, the macromolecules near the interface can be highly oriented due to the flow history. Weld interfaces would vanish very quickly in a low molecular weight material. However, macromolecules need a long time to diffuse across the interface and to relax to a random configuration. The influence of flow-induced orientation on the welding process is largely unknown.

This work establishes a mathematical model quantifying orientation development in two-dimensional welding flows of polymer liquids and tests the model experimentally. The modelling consists of three phases: 1. Determination of the approximate kinematics by using a finite element analysis. 2. Integration of the deformation history by tracking material elements based on continuum mechanics. 3. Calculation of the stress by using a memory integral constitutive equation. The modelling applies to molten homopolymers. The geometric model for welding flows is considered to be a two-dimensional flow past an obstacle in a slit. The shape of the obstacle can be a plate, a slab, or a cylinder.

A slit die with two side windows was constructed for studying welding. The obstacle was a thin plate located at the center of the slit. Molecular orientation near a weld interface was investigated by extruding polystyrene (PS) or low density



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polyethylene (LDPE) through the die and measuring the flow-birefringence. The experimental results show that macromolecules are highly oriented near the weld interface close to the tip of the plate and that the oriented region is about two or three times as thick as the plate. Further downstream, the orientation near the weld interface decreases in both magnitude and thickness. The relaxation of the oriented layer depends strongly on molecular structure. The low chain-branching PS relaxes very quickly, while the high long-chain-branching LDPE relaxes very slowly.

The analysis shows that fluid elements near a weld interface have a strain history consisting of both high shear and extension. The birefringence calculated from the model and the measured birefringence are in good agreement, especially in regions of small deformations. The model is insensitive to small perturbations in the kinematics and it is reasonably insensitive to small changes in rheological parameters. In summary, the model works well provided the real and approximate kinematics have common basic features; for example, no additional recirculation is allowed.

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